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Comparison of Terrestrial Gamma-Ray Flash Simulations with Observations by Fermi

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Approved for public release; distribution is unlimited.
Results will be reported in a publication to be submitted to the Journal of Geophysical Research-Space

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**
For this project Monte Carlo simulations of terrestrial gamma rays flashes (TGFs) were preformed and results compared with spacecraft observations, including results from Fermi, and other simulations. As a result of this work, a paper has been written and will be submitted to the Journal of Geophysical Research-Space (Dwyer et al. 2016). For this paper, Monte Carlo simulations are used to determine source properties of terrestrial gamma-ray flashes (TGFs) as a function of atmospheric column depth and beaming geometry. The total mass per unit area traversed by all the runaway elections (i.e., the total grammage) during a TGF, , is introduced, defined to be the total distance traveled by all the runaway electrons along the electric field lines multiplied by the local air mass density along their paths. It is shown that key properties of TGFs may be directly calculated from and its time derivative, including the gamma-ray emission rate, the current moment, and the optical power of the TGF. For the calculations presented in this paper, the standard TGF gamma-ray fluence F0 = 0.1 cm-2 for a spacecraft altitude of 500 km and the standard total grammage = 1018 g/cm2 are introduced, and results are presented in terms of these values. In particular, the current moments caused by the runaway electrons and their accompanying ionization are found for a standard TGF fluence, as a function of source altitude and beaming geometry, allowing a direction comparison

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**Final Report for the project titled "Comparison of Terrestrial gamma ray flash simulations with observations with Fermi." (Award No.: N00173151G014; PI: Joseph R. Dwyer)**

For this project Monte Carlo simulations of terrestrial gamma rays flashes (TGFs) were preformed and results compared with spacecraft observations, including results from Fermi, and other simulations. As a result of this work, a paper has been written and will be submitted to the Journal of Geophysical Research-Space (Dwyer et al. 2016). For this paper, Monte Carlo simulations are used to determine source properties of terrestrial gamma-ray flashes (TGFs) as a function of atmospheric column depth and beaming geometry. The total mass per unit area traversed by all the runaway elections (i.e., the total grammage) during a TGF, $\mathsf{X}$, is introduced, defined to be the total distance traveled by all the runaway electrons along the electric field lines multiplied by the local air mass density along their paths. It is shown that key properties of TGFs may be directly calculated from $\mathsf{X}$ and its time derivative, including the gamma-ray emission rate, the current moment, and the optical power of the TGF. For the calculations presented in this paper, the standard TGF gamma-ray fluence $F_0$ = 0.1 cm$^{-2}$ for a spacecraft altitude of 500 km and the standard total grammage $\mathsf{X}_0$ = $10^{18}$ g/cm$^2$ are introduced, and results are presented in terms of these values. In particular, the current moments caused by the runaway electrons and their accompanying ionization are found for a standard TGF fluence, as a function of source altitude and beaming geometry, allowing a direction comparison between the gamma rays measured in low-Earth orbit and the VLF-LF radio frequency emissions recorded on the ground. Such comparisons should help test and constrain TGF models and help identify the roles of lightning leaders and streamers in the production of TGFs.

As examples of this work, Figure 1 shows model results for the fluence of gamma rays with energies >100 keV at a 500 km altitude versus the horizontal distance of the TGF from the spacecraft nadir point. Plots are shown for different gamma ray beam widths. Figure 2 shows the model results for the vertical current moment inside a thunderstorm generated during a TGF.

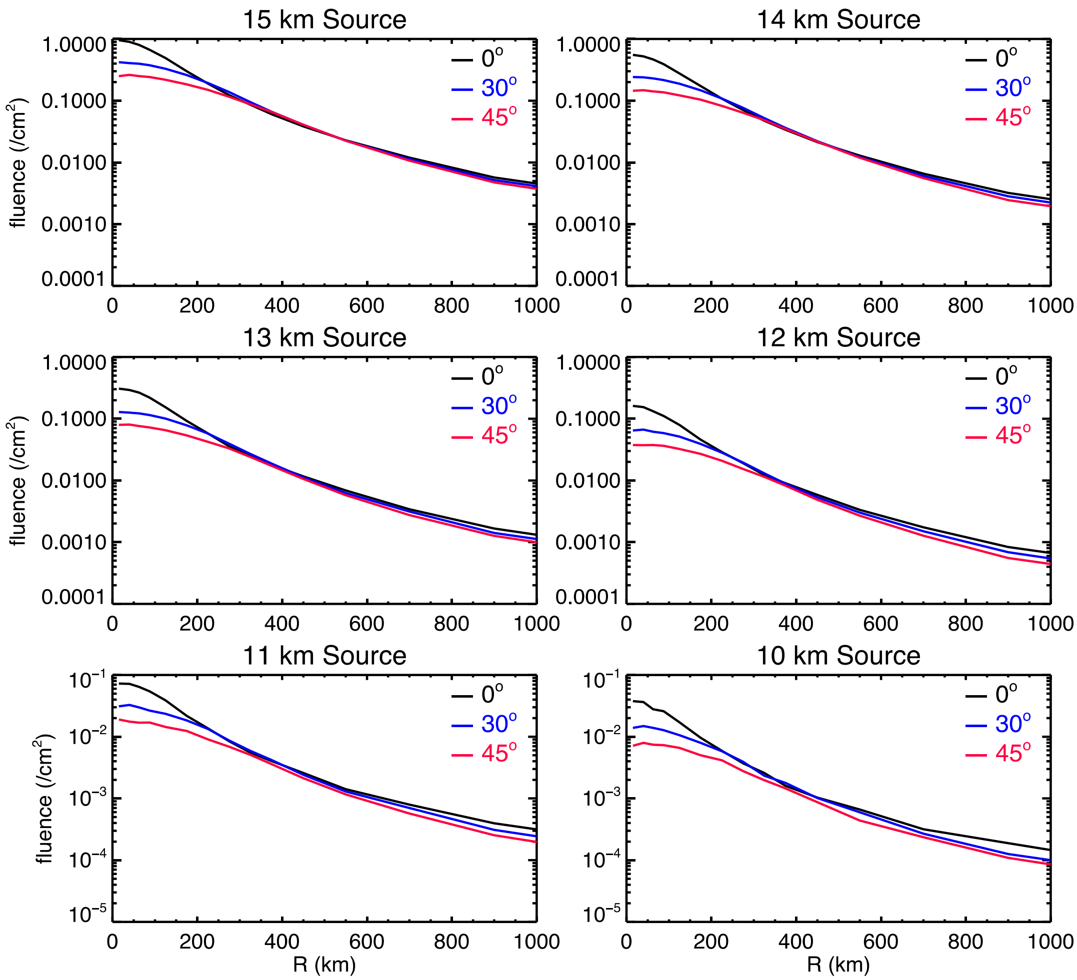


**Figure 1.** TGF fluence for gamma-ray energies >100 keV versus horizontal distance of the TGF from the nadir point. The three curves in each panel are for a 0° beam width, a 30° beam width, and a 45° beam width.

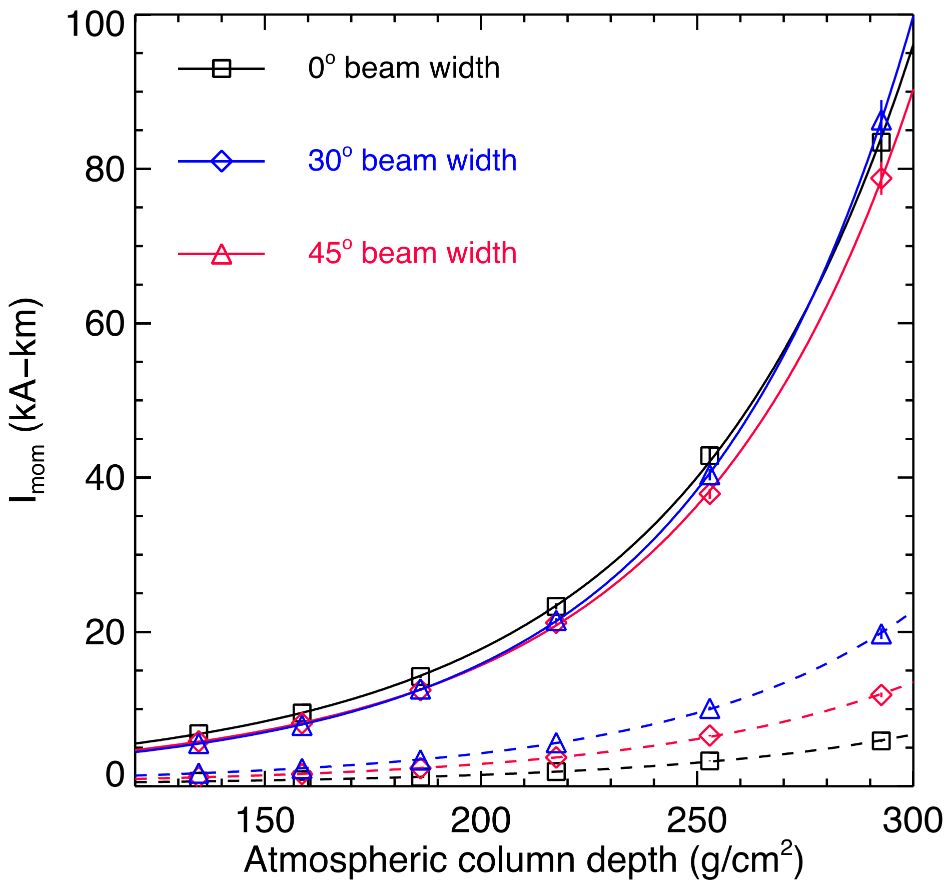


**Figure 2.** The peak vertical current moment versus atmospheric column depth for a standard TGF with a fluence of 0.1 cm$^{-2}$ (> 100 keV) at a spacecraft altitude of 500 km. The top three lines and data are for TGFs 300 - 400 km from the nadir point and the bottom three are for TGFs 0 -100 km from the nadir point.

**Reference**


Dwyer, J. R., N. Liu, J. E. Grove, H. Rassoul, and D. M. Smith, Characterizing the source properties of terrestrial gamma-ray flashes, J. Geophys. Res., 2016 In preparation.